CLAIMS

We Claim:

1. A microelectromechanical system (MEMS) strain gauge providing measurement of strain of an object, the strain gauge comprising:

a substrate having a surface attachable to the object;

a longitudinally extending beam;

at least one flexible arm having first and second ends attached to the substrate and having a middle portion supporting the beam above the substrate; and

a detector communicating with the beam for detecting a frequency of vibration of the beam to provide a measure of strain of the object.

2. The MEMS strain gauge as recited in claim 1, wherein the detected frequency is a resonant frequency of vibration of the beam.

3. The MEMS strain gauge as recited in claim 1, further including a first actuator communicating with the beam to apply a force to the beam.

4. The MEMS strain gauge as recited in claim 3, further comprising a second actuator connected to the beam for providing a force to the beam in a direction opposite the force provided by the first actuator.

5. The MEMS strain gauge as recited in claim 3, wherein the detector comprises a set of movable capacitor plates connected to the beam and a set of stationary capacitor plates in opposition to the movable capacitor plates and a capacitance sensing circuit.

6. The MEMS strain gauge as recited in claim 3, wherein the applied force induces vibration in the beam.

7. The MEMS strain gauge as recited in claim 6, wherein the applied force is an impulse that induces vibration in the beam at a resonant frequency of the beam.

8. The MEMS strain gauge as recited in claim 6, wherein the first actuator comprises a set of movable capacitor plates connected to the beam and a set of stationary capacitor plates in opposition to the movable capacitor plates.

9. The MEMS strain gauge as recited in claim 6, wherein the movable and stationary capacitor plates have interdigitating fingers.

10. The MEMS strain gauge as recited in claim 6, wherein the first actuator further comprises a pulse generator connected across the movable and stationary capacitor plates and operable to momentarily charge the capacitor plates to produce the force.

11. The MEMS strain gauge as recited in claim 6, wherein the first actuator further comprises a variable ac oscillator connected across the movable and stationary capacitor plates and operable to maintain oscillation at a resonant frequency of the transverse arm.

12. The MEMS strain gauge as recited in claim 6, wherein the first actuator further comprises an ac oscillator connected across the movable and stationary capacitor plates and operable to maintain oscillation at a predetermined frequency of the transverse arm.

13. The MEMS strain gauge as recited in claim 12, further comprising a microprocessor coupled to the detector to calculate the strain at the arm as a function of the amplitude of motion of the beam as it vibrates at the predetermined frequency.

14. The MEMS strain gauge as recited in claim 2, further comprising a microprocessor coupled to the detector to calculate the strain at the arm as a function of the resonant frequency of the arm.

15. The MEMS strain gauge as recited in claim 14, wherein the microprocessor further measures frequency comprises a frequency measurement counter counting cycles of capacitance variation for a predetermined time period.

16. The MEMS strain gauge as recited in claim 15, wherein the microprocessor calculates an amplitude of motion and maintains the frequency at a specific frequency.

17. The MEMS strain gauge as recited in claim 16, wherein the specific frequency is a resonant frequency.

18. The MEMS strain gauge as recited in claim 1, wherein the beam is centered on the arm between the first and second ends of the flexible arm.

19. The MEMS strain gauge as recited in claim 1, wherein the flexible arm supports the beam at a first end of the beam, and wherein the strain gauge further includes a second flexible arm having first and second ends attached to the substrate and having a middle supporting the beam above the substrate at a second end of the beam.

20. The MEMS strain gauge as recited in claim 1, wherein the arm is electrically isolated from the object.

21. The MEMS strain gauge as recited in claim 1, wherein the arm is electrically isolated from the detector.

22. The MEMS strain gauge as recited in claim 2, wherein the arm is electrically isolated from the first actuator.

23. The MEMS strain gauge as recited in claim 1, wherein at least a portion of the beam is insulating.

24. The MEMS strain gauge as recited in claim 1, further including:

a second flexible arm having first and second ends attached to the substrate and having a middle supporting the beam above the substrate; and

a detector communicating with the arm for detecting a frequency of vibration of the second arm to provide a measure of strain of the object.

25. A method for sensing the strain of an object using a MEMS strain gauge including a longitudinally extending beam suspended over a substrate by an arm connected at two separated ends to the substrate along a transverse axis, the method comprising the steps of:

A) attaching the substrate to the object with the transverse axis aligned with a direction of strain measurement in the object so that strain of the object causes strain in the substrate;

B) providing a momentary force to the arm, thereby causing the arm to vibrate at a frequency, wherein the frequency of vibration is dependent upon the strain of the substrate and object;

C) measuring the frequency of vibration; and

D) based on the measured frequency of vibration, determining the strain of the object.

26. The method as recited in claim 26, wherein step (B) further comprises causing the arm to vibrate at a resonant frequency.

27. The method as recited in claim 27, wherein step (C) further comprises measuring the resonant frequency of vibration.

28. The method as recited in claim 28, wherein step (D) further comprises determining the strain of the object based on the measured resonant frequency of vibration.

30. The method as recited in claim 25, wherein step (D) further comprises adjusting a displacement of the arm to maintain the vibration at a predetermined frequency, and determining the strain based on the amount of displacement.

31. A microelectromechanical system (MEMS) strain gauge providing measurement of strain of an object, the strain gauge comprising:

a substrate having a surface attachable to the object;

at least one flexible arm having first and second ends attached to the substrate, wherein the arm oscillates in response to a stimulus; and

a detector communicating with the arm for detecting a frequency of oscillation of the arm to provide a measure of strain of the object.

32. The MEMS strain gauge as recited in claim 31, wherein the detector comprises a capacitor plate interfacing with the arm.

33. The MEMS strain gauge as recited in claim 32, wherein the detector measures capacitance across the capacitor plate and the arm.

34. The MEMS strain gauge as recited in claim 33, further comprising a microprocessor coupled to the detector and calculating an oscillation frequency of the flexible arm.

35. The MEMS strain gauge as recited in claim 31, wherein the flexible arm carries a plurality of capacitor fingers, and wherein the detector comprises a capacitor plate carrying a plurality of capacitor fingers interdigitating with the capacitor fingers of the flexible arm.

36. The MEMS strain gauge as recited in claim 31, further comprising an actuator capable of applying a force causing the flexible arm to oscillate.

37. The MEMS strain gauge as recited in claim 31, wherein the arm carries a plurality of capacitor fingers, and wherein the actuator comprises a capacitor plate carrying a plurality of capacitor fingers that are interdigitated with the capacitor fingers of the arm.

38. The MEMS strain gauge as recited in claim 37, wherein a momentary voltage is applied across the capacitor plate.

39. The MEMS strain gauge as recited in claim 38, wherein the capacitance across the interdigitated fingers is sensed after the voltage is applied.

40. The MEMS strain gauge as recited in claim 39, wherein an oscillation frequency is determined based on the sensed capacitance.

41. The MEMS strain gauge as recited in claim 40, wherein the strain is determined based on the oscillation frequency.